Name Date

ENGINEERING LAB

Testing a Bridge

People have depended on bridges for transporting goods and people throughout history. When a bridge collapses, it can damage goods and cause injury or death to people both above and below the bridge. For these reasons, civil engineers must design bridges that can withstand a variety of different loads. The load on a bridge is due to the bridge's own weight and the dynamic, external loads from traffic, people, wind, and other environmental forces. A bridge's ability to withstand a load depends on several factors, including the amount of force exerted by the load, the location and direction of the force, and the area over which that force acts. Bridges should be evaluated and updated periodically to maintain function and safety because bridge structure may degrade over time.

MATERIALS

- safety goggles
- books, equal thickness (2)
- paper, 20 lb (4 sheets)
- pennies (or other small masses) (50)
- ruler, metric

Your civil engineering firm has been hired to evaluate a bridge. City officials need to know how the bridge will perform under the loads of its upcoming refurbishment project. The project consists of three main phases. In phase 1, heavy machinery will enter the bridge from one side and park there during planning activities. In phase 2, the heavy machinery will park in the middle of the bridge while performing maintenance. In phase 3, the road will be reopened to the public, during which rush hour stop-and-go traffic will have cars spaced all along the bridge. The city officials are specifically interesting in knowing if the amount of load the bridge can support is dependent on how the load is distributed.

City officials have given your civil engineering company the design for the bridge. In this lab, you will design models for the load conditions of the three phases and use your models to test the bridge.

DESIGN CHALLENGE Design models for the loads on a bridge during phase 1, phase 2, and phase 3 of a refurbishment project. Use these models to test and evaluate the strength of the bridge to advise city officials about safety precautions related to the load on the bridge.

SAFETY INFORMATION

- Wear safety goggles during the setup, hands-on, and takedown segments of the activity.
- Immediately pick up any items dropped on the floor so they do not become a slip/fall hazard.
- Wash your hands with soap and water immediately after completing this activity.

CONDUCT RESEARCH

Engineers use force diagrams to analyze the external and internal forces on an object in certain situations. Research how a force diagram would be drawn for part of an object that is not accelerating. Recall that an object at rest, such as a bridge, should have a net force of 0 N.

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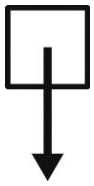
Consider the following to further help understand the forces on parts of a bridge.

1. The diagram is an incomplete force diagram for the center section of a standing bridge. Complete the diagram, and then explain your reasoning for how you completed it.

Force Diagram of the Center Section of a Bridge



2. Place two books flat on a table and position them approximately 15 cm apart. Place a flat sheet of paper lengthwise over the gap between the books. Make sure the paper is supported equally at each end. Place a small mass (3–5 pennies) in the middle of the paper. Describe what happens to the ends of the paper near the supporting books and what happens in the middle of the paper. What can you conclude about the directions and strengths of forces acting on the paper?

DEFINE THE PROBLEM

1. Write a statement identifying the problem you are designing a solution for. How will you evaluate your design?

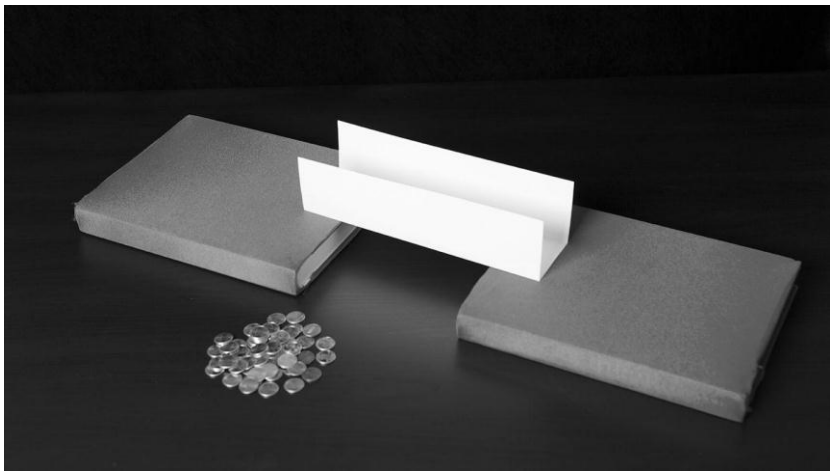
2. Identify the criteria for a successful test plan. Explain why you included each criterion.

3. Identify the constraints that will limit a successful test plan.

DESIGN SOLUTIONS

All of your testing should be performed on a paper bridge model. The bridge model should be folded from a sheet of 20 lb paper. Using a ruler or straight-edge, draw two diagonal lines connecting the opposite corners of the paper. Where these lines cross is the center of the bridge. Then fold the paper lengthwise so that one long edge of the paper meets the center. Repeat this fold on the other side so that the paper is folded into three sections, as shown in Figure 1. Because each test results in a bridge failure, you will need to make a paper bridge model for each test.

Figure 1



Source: ©HMH

A folded piece of paper forms a bridge between two books, about 15 cm apart.

Make a plan for how you will model the load conditions of phases 1, 2, and 3. Sketch these models in the table below, and explain how each model will help you test the conditions of that phase.

Phase	Sketch load model	Explain how each model represents the different loads
Phase 1		
Phase 2		
Phase 3		

TEST

In your Evidence Notebook, write a test plan. Each load distribution should be tested until the bridge fails. Your test plan should explain how you will model the load, the criteria for bridge failure, independent and dependent variables, as well as a detailed procedure. Show your test plan and models to your teacher, and get approval before proceeding.

Perform the tests described in your plan. In your Evidence Notebook, record the conditions under which the bridge fails for each phase. Also record qualitative observations of the bridge behavior as the load is added and when the bridge collapses.

ANALYZE

1. How does the bridge behavior change under the different loads? Did the load distribution effect how much mass the bridge was able to support before failing? Explain why, drawing diagrams in your Evidence Notebook if needed.

2. Compare what you observed when you placed a small load on a flat sheet of paper with what you observed when you placed a similar load on a folded sheet of paper. Why does folding the paper change the results?

3. Which phase of the project should most concern city officials? Explain your reasoning.

OPTIMIZE

Reflect on your test procedure. Remember, the city officials need accurate information on how the bridge is likely to perform under the loads of each planned phase. Suggest one way you could modify your test procedure to better meet this need. Explain why this modification would be an improvement.

COMMUNICATE

Use the points below to formulate a report for the city officials.

Claim What safety precautions should city officials consider during each phase of the refurbishment project?

Evidence What evidence from your investigation supports your claims?

Reasoning Explain how the evidence you provide supports your claim. Describe, in detail, the connections between the evidence you cited and the argument you are making.

EXTEND

Construct a different bridge design. For example, you might use another type of paper or fold the paper differently. Repeat the load distribution test on the new design. Compare the function of the new bridge design to the original design. Explain why the bridge function changed, using diagrams if helpful.